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Network-Level Information Models for Integrated ATM/SONET/WDM Management*

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Abstract

To sustain the ever growing demand for bandwidth in cost-effective, efficient and robust ways, it is anticipated that the next-generation transport network architecture will consist of several different technology layers. However, managing such multi-layered transport networks will be complicated and difficult, due to the scale of the networks and the correlation between different technology layers. Unfortunately, existing network management systems mainly manage a single technology, and management systems for different technologies may not interoperate. Therefore, to effectively manage the emerging multi-layered transport networks, an *integrated* network management system is urgently needed. In this paper, we describe work on integrated management of ATM/SONET/WDM networks from both information modeling's and software architecture's perspectives. We describe how the standard work on network-level information models may be used to model different transport technology layers and their inter-relationships. We will also describe how the CORBA technology may be used to realize the integrated information model so that the resulting integrated network management system is distributed and complies with TMN Logical Layered Architecture.

Keywords:

ATM
CORBA
Integrated Network Management
Network-Level Information Model
SONET
TMN
WDM

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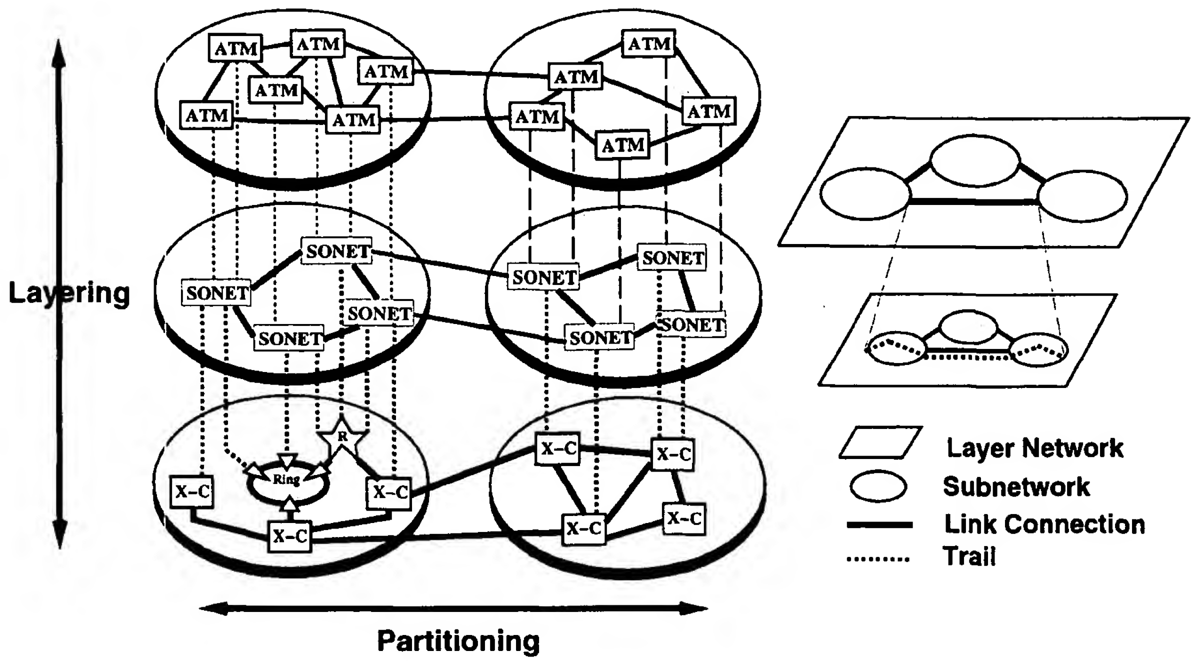
Transport Network Architecture



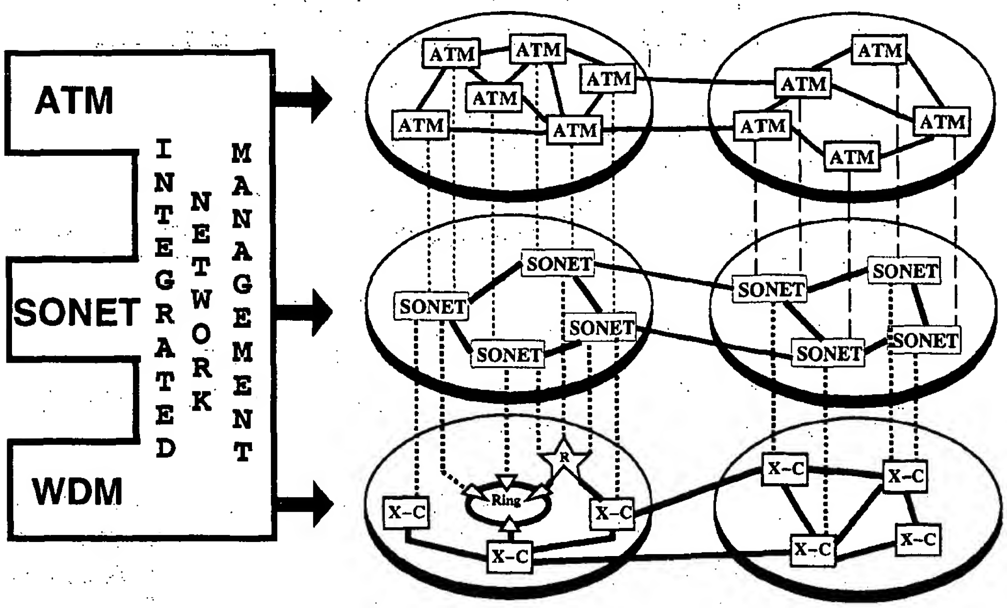
To sustain the ever growing demand for bandwidth in cost-effective, efficient and robust ways, multiple transport technologies have been developed. Among them, ATM, SONET, and WDM are some of the most significant ones. ATM had been identified as the transport technology for B-ISDN to facilitate integrated multimedia services. However, ATM cells cannot be sent directly over an optic fiber link, where some rules are required to encode ATM cells and mark cell boundaries. In turn, SONET provides the physical layer support and transmits ATM cells in SONET frames. In addition to framing, SONET network elements and architectures provide multiplexing and protection capability for cost-effective and robust transport, respectively. Furthermore, with the advancement of the *reconfigurable* WDM technology, it is more cost-effective to transmit several optical signals at different wavelengths on the same fiber, where each individual wavelength may carry SONET or other traffic. Therefore, it is anticipated that the next-generation transport network architecture will be multi-layered and consist of ATM, SONET, and WDM technologies.

To manage the complexity of different technologies, a transport network can be decomposed into a number of independent transport *layer networks* with a *client/server* relationship between adjacent layer networks [1]. Each layer network is characterized by the type of information it transfers, which is closely tied to a specific type of network transmission and/or switching technology. For example, the next-generation transport network can be decomposed into ATM, SONET, and WDM layer networks.

To manage its own complexity, each layer network can be separately *partitioned* into subnetworks and links to reflect the topology or management boundary of that layer network [1]. Each subnetwork may be further decomposed recursively into smaller subnetworks interconnected by links until the desired level of detail is revealed. This will generally be when the subnetwork is equivalent to a single switch or cross-connect.

By combining the concepts of both layering and partitioning, a *link connection* in a upper (client) layer network is provided by the services of a *trail* in a lower (server) layer network.

Integrated Network Management



However, managing such multi-layered transport networks will be complicated and difficult, due to the *scale* of the networks and the *correlation* between different technology layers. For example, a performance degradation at the lowest WDM layer will have domino effects on connections on SONET and ATM layers. Unfortunately, existing network management systems mainly manage a single technology, and management systems for different technologies may not interoperate. Therefore, to effectively manage the emerging multi-layered transport networks, an *integrated* network management system is urgently needed.

From the software system's perspective, management functions together with information models constitute a network management system[1]. Therefore, the key to successful software development of integrated network management is an information model that represents global views of layer networks, the relationships between layer networks, and how layer networks are interconnected and configured to provide end-to-end connectivity.

To support global, end-to-end views of transport networks, we adopt standard-based *network-level* information models which define network information objects and relationships. We also propose to define and implement network information objects using CORBA [2]. From the software development's point of view, the network-level information model is implemented as a collection of CORBA objects which serve as a *distributed data structure* to be manipulated by network management functions. These CORBA objects may be organized into Network Management Layer (NML) and Element Managerment Layer (EML) so that the resulting network management system complies with TMN Logical Layered Architecture [3] and scales with the growth of transport networks.

[1] It is motivated by the well-acknowledged concept of 'software program = algorithms + data structures.'

Network–Level Information Models

* Network–level information models
  - TINA–C: Network Resource Information Model (NRIM)
  - ITU SG 4: Common Information Viewpoint
  - SIF: Network–Level Model for Network Connection Management
  - ATM Forum: M4 Network View CMIP MIB

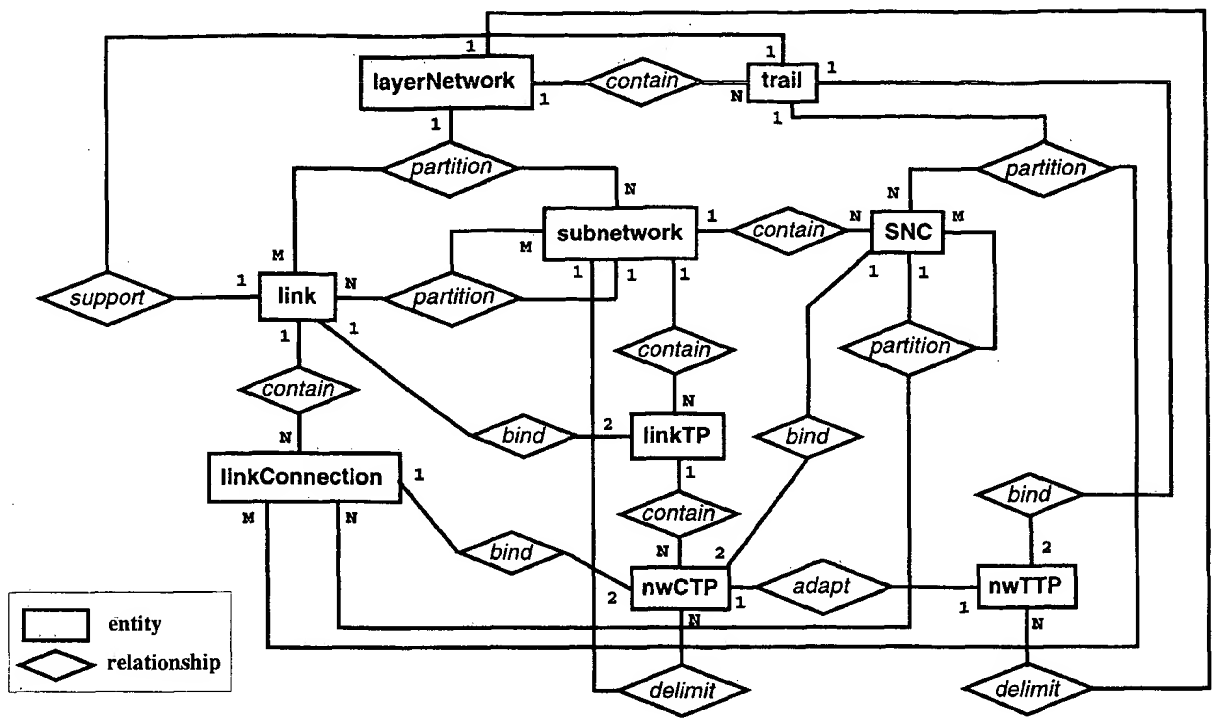
* Represent a global view of transport networks and consider how individual network elements are interconnected and configured to provide end–to–end connectivity

* Layer network, SNW, Link, Link TP, Link connection, SNC, nwCTP, nwTTP, Trail

Recent standard activities on information modeling has been focusing on defining network-level information models. For example, ITU-T Study Group 4 proposes the Draft Recommendations G.853-01: Common Information Viewpoint [4], TINA-C defines the Network Resource Information Model (NRIM) [5], SONET Interoperability Forum (SIF) defines Network-Level Model for Connection Management [6], and ATM Forum has M4 Network View MIB [7]. These network-level information models represent a global view of transport networks and consider how individual network elements are interconnected and configured to provide end-to-end connectivity. The information models contain definitions of information objects and their relationships that provide transmission and switching technology-independent information specifications of network resources. For example, the following information objects will represent network-level resources and concepts.

- **Layer Network.** A layer network is a transport network that carries a particular characteristic information. For the emerging transport networks, we have ATM, SONET, and WDM layer networks.
- **Subnetwork.** A subnetwork contains other subnetworks and links that are grouped together for topological or other reasons. The smallest subnetwork is a physical NE.
- **Link.** A Link is a topological component that describes a topological relationship between two subnetworks along with transport capacity. For WDM, a link represents an optical fiber.
- **Link Termination Point (LinkTP).** A LinkTP represents an end point of a link.
- **Link Connection (LC).** A link connection is the resource that transfers the characteristic information between two subnetworks.
- **Network Connection Termination Point (nwCTP).** A nwCTP represents an end point of a subnetwork connection or link connection.
- **Subnetwork Connection (SNC).** A subnetwork connection is the resource that transfers information between two nwCTPs at the edge of the subnetwork. For the degenerated case where a subnetwork represents a network element, an SNC denotes a cross-connect in the switching fabric. A subnetwork connection is delimited by two nwCTPs.
- **Network Trail Termination Point (nwTTP).** The nwTTPs delimit a layer network. There are the access points for client layer networks.
- **Trail.** An end-to-end trail is the resource that transfers information between two nwTTPs. Trails support the client layer link connections.

Entity–Relationship Diagram for Network–Level Information Model

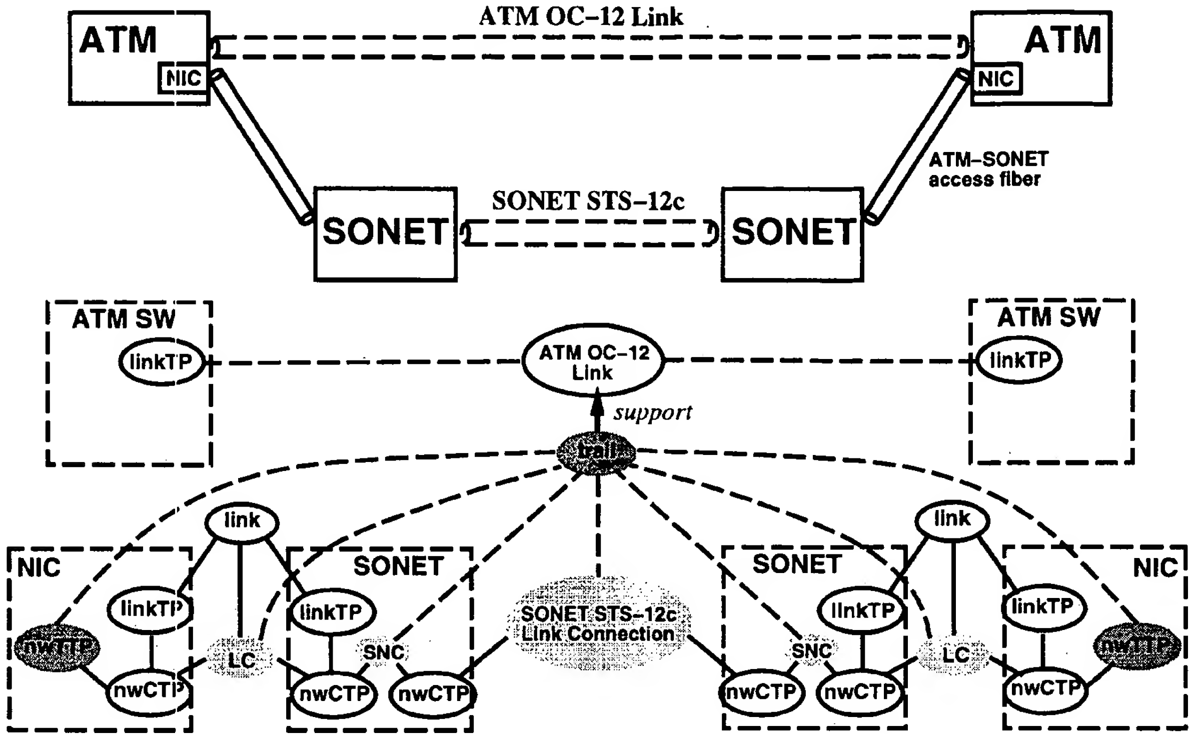


These network-level models have adopted a GDMO-based notation to define information objects and used GRM (General Relationship Model) to specify how information objects are related. Together, they can be depicted by an *Entity-Relationship Diagram.* For example, the E-R diagram shows the following relationships.

- **Partition.** A layer network may be partitioned into a set of links and subnetworks, and each subnetwork may recursively be partitioned into subnetworks and links. A SNC may be partitioned into SNCs and LCs.
- **Contain.** A layer network contains several trails. A link may contain LCs. A subnetwork may contain SNCs. Each linkTP contains several nwCTPs. A link contains several LCs.
- **Bind.** A link is bound to two linkTPs. An LC is bound to two nwCTPs. A SNC is bound to two nwCTPs, and a trail is bound to two nwTTPs.
- **Support.** A trail in the server layer network supports a link in the client layer network.[2]
- **Adapt.** It describes the relationship existing between nwCTPs of a client layer network and the nwTTPs that support them in a server layer network.
- **Delimit.** A layer network is delimited by a set of nwTTPs whose associations may be setup and tear-down by the layer network connection management process. Similarly, a subnetwork is delimited by a set of nwCTPs.

[2]The supported link may in turn contain other LCs.

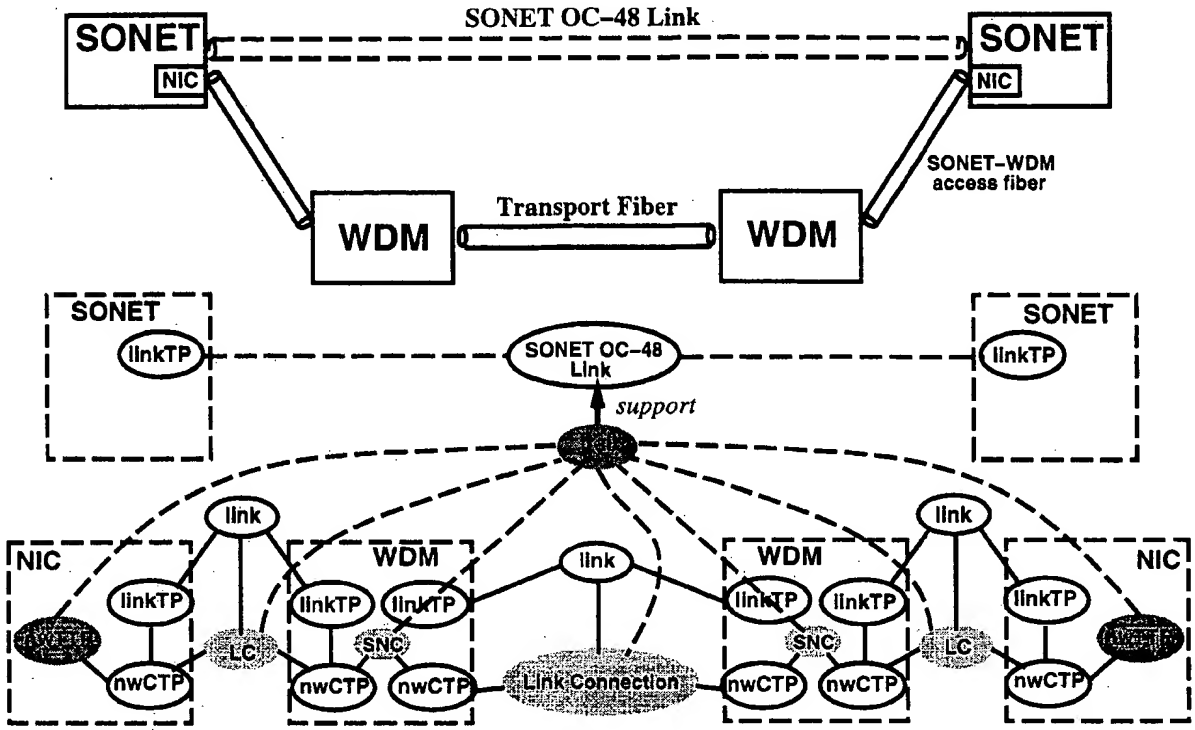
ATM over SONET



The figure depicts ATM over SONET, where two ATM switches are connected by a (logical) OC-12 link. In practice, it may be realized by plugging an OC-12 NIC (Network Interface Card) into an ATM switch. The NIC has an ATM-SONET access fiber which connects the NIC to the lower-speed (OC-12) card of a SONET OC-48 ADM (Add-Drop Multiplexer). In addition, an STS-12c connection is setup in the SONET layer between two ADMs. End-to-end (NIC-to-NIC), there is an STS-12c SONET *path* created which serves as a trail in the SONET (server) layer and supports an ATM OC-12 link connection in the ATM (client) layer.

The corresponding network-level information model is shown. Logically, an ATM OC-12 link binds to two linkTPs of the corresponding ATM switches. In practice, two link objects denote the two ATM-SONET access fiber links. Within a SONET ADM, there are nwCTPs bound to LC and STS-12c LC, respectively. An SNC is created, which binds to the two nwCTPs within a SONET ADM and denotes a *cross-connect* within the SONET ADM fabric. The SNC is the result of an *add* or a *drop* operation as part of an end-to-end connection setup. A trail is formed by combining two nwTTPs, two LCs over the access links, two SNCs within the ADMs, and the STS-12c LC. This trail supports the ATM OC-12 link between two ATM switches.

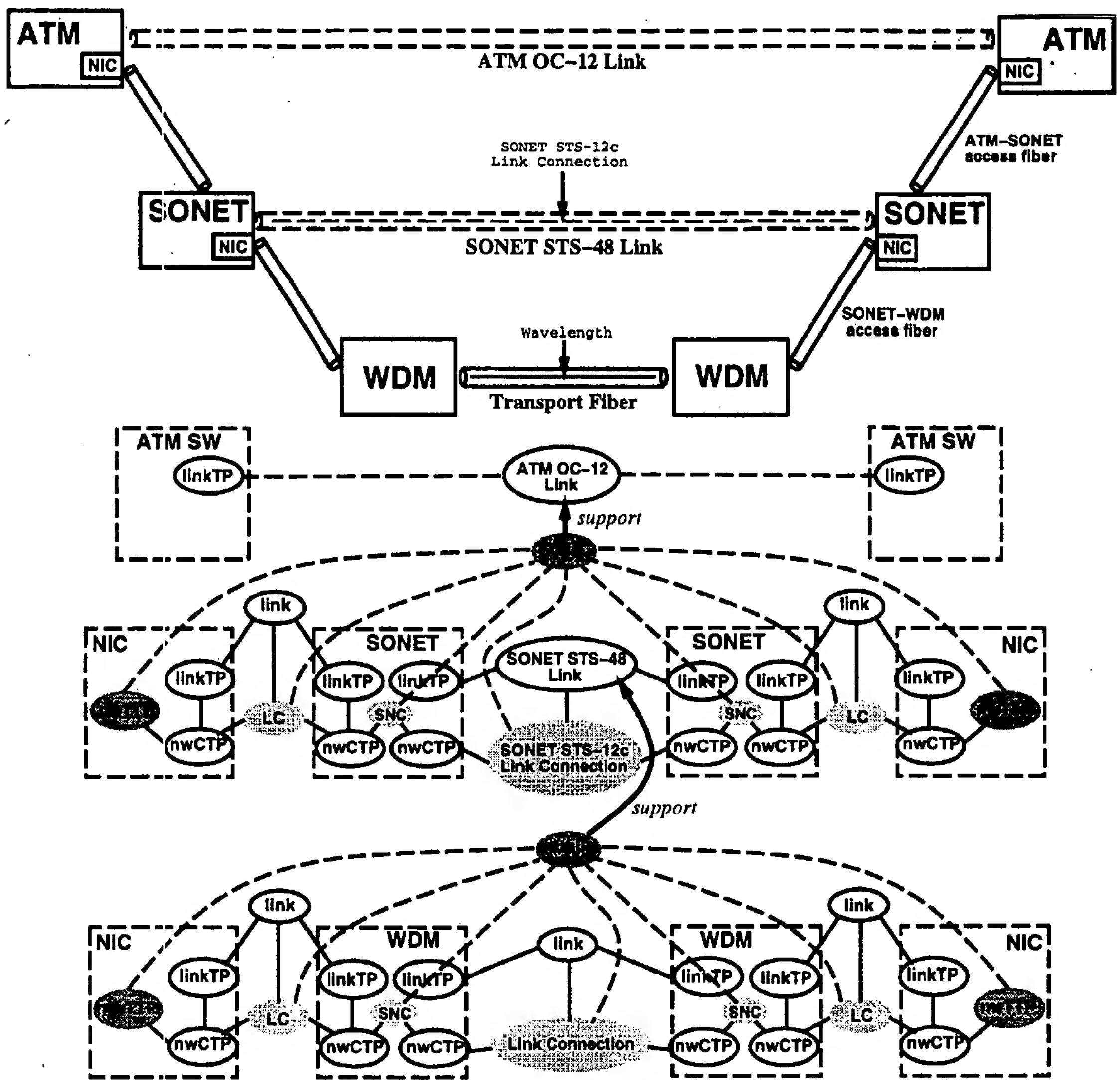
SONET over WDM



The figure depicts SONET over WDM, where two SONET ADMs are connected by a (logical) OC-48 link. In practice, it may be realized by plugging an OC-48 NIC into a SONET ADM. The NIC has a SONET-WDM access fiber which connects the NIC to a *client interface card* of a WADM (Wavelength Add-Drop Multiplexer). The NIC could have wavelength translation capability which translates the SONET optical signal into a *compliant* wavelength supported by the WADM. In addition, a wavelength connection is setup in the WDM layer between two WADMs. End-to-end (NIC-to-NIC), there is a WDM *path* created which serves as a trail in the WDM (server) layer and supports a SONET OC-48 link connection (a SONET *section*) in the SONET (client) layer.

The corresponding network-level information model is shown. Logically, a SONET OC-48 link binds to two linkTPs of the corresponding SONET ADMs. In practice, two link objects denote the two SONET-WDM access fibers, and another link object denotes the transport fiber connecting the two WADMs. Within a WADM, there are nwCTPs bound to LC within the transport fiber and LC within the access fiber, respectively. Similarly, an SNC is created, which binds to the two nwCTPs within a WADM and denotes a *cross-connect* within the WADM fabric. The SNC is the result of an *add* or a *drop* operation as part of an end-to-end wavelength setup. A trail is formed by combining two nwTTPs, two LCs over the access links, two SNCs within the WADMs, and the wavelength LC. This trail supports the SONET OC-48 link between two SONET ADMs.

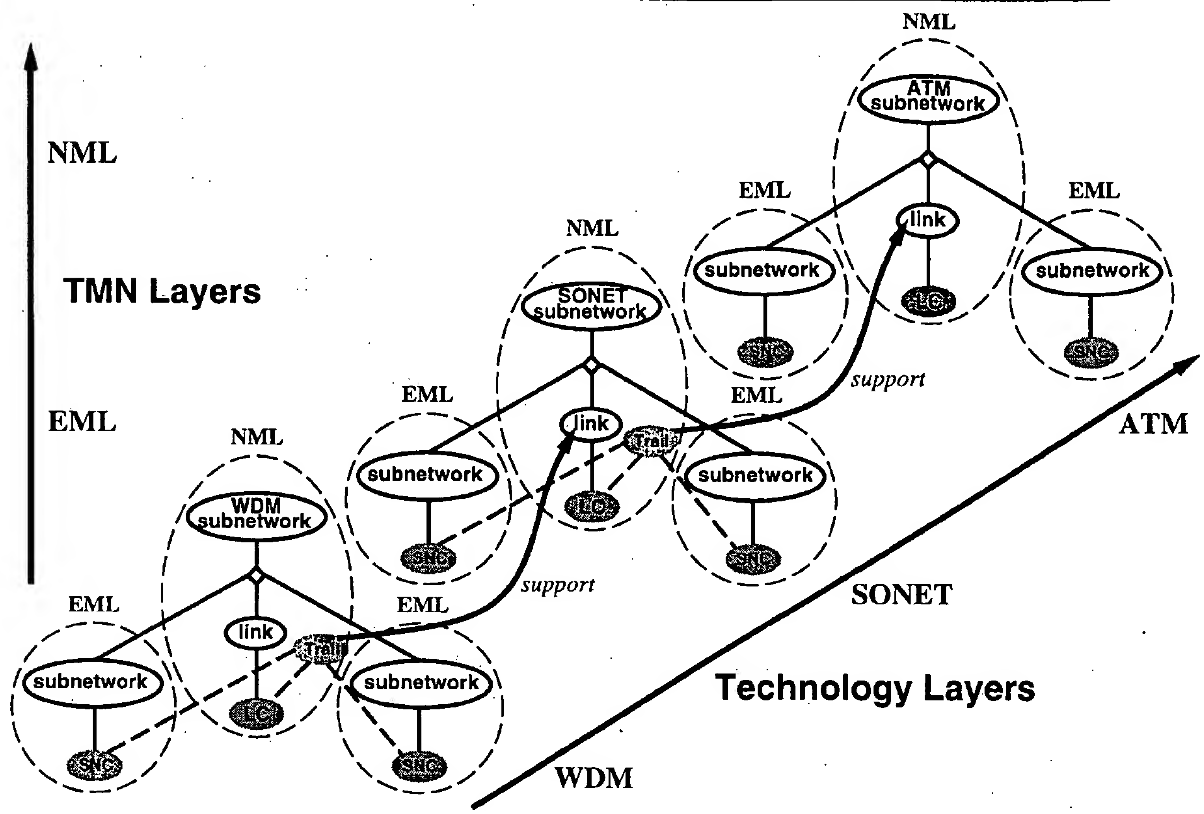
ATM over SONET over WDM



By putting all three layers together, we have the figure showing that an ATM OC-12 link routes over a SONET STS-12c path, where the transport section of the STS-12c is a link connection within a SONET STS-48 link supported by a wavelength path within fibers in the WDM layer.

The corresponding *integrated* network-level information model is shown. An LC (wavelength) within the transport fiber together with other transport entity objects (SNCs and LCs within access fibers) form a trail in the WDM layer. The trail supports a SONET STS-48 link. Contained within the SONET STS-48 link, a SONET STS-12c link connection is setup, which together with other transport entity objects form a trail in the SONET layer. In turn, the trail supports an ATM OC-12 link between two ATM switches.

Software Architecture for Integrated Information Model

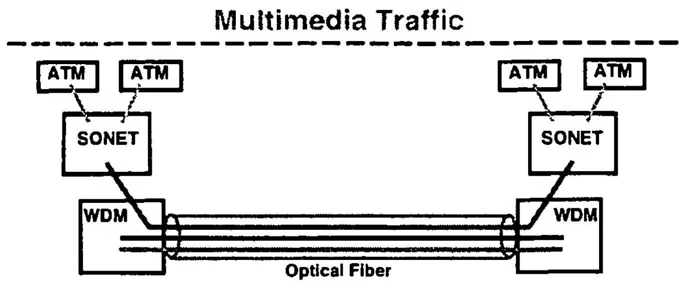


In addition to being capable of managing multiple technology layers, the integrated network management system should also be able to scale.

The figure shows a three-dimensional view of the integrated network-level information model. Along the 'technology layers' axis, we have information models organized for ATM, SONET, and WDM layer networks. Relationships between adjacent layers are denoted the concept that a trail in the server layer supports a link connection is the client layer. Along the 'TMN layers' axis, the information model for each technology is organized into NML and EML layers according to subnetwork hierarchy for scalability.

From the software architecture's perspective, information objects and their relationships are realized by CORBA objects. These CORBA objects are organized along both the TMN layers and the technology layers. These CORBA objects may be deployed across management workstations which are located in different geographical areas and operated by people structured in different organizations (for different technologies). However, a consistent and integrated transport network information model is maintained, which is shared by all management applications that can navigate and retrieve the information needed for their processing.

Conclusions



* Multi-layer transport network architecture to provide bandwidth in cost-effective, efficient, and robust ways: ATM/SONET/WDM
* Integrated network managment is crucial to ensure required QoS
* CORBA-based architecture: distributed and TMN layer-compliant
* Testbed networks: ATDNet (ATM/SONET) and MONET (reconfigurable WDM)

To satisfy bandwidth demands of multimedia applications in cost-effective, efficient and robust ways, it is anticipated that the next-generation transport network will be made up of ATM, SONET, and WDM technologies. To ensure the required QoS, a comprehensive and integrated network management is urgently needed. This paper describes an integrated network-level information model which represents layer network resources and their relationships, and scales according to subnetwork hierarchy. The resulting information model may be realized in CORBA, which is distributed and complies with TMN Logical Layered Architecture. Work is in progress to prototype an integrated ATM/SONET/WDM network management system by integrating ATDNet (ATM/SONET) [8] and MONET (reconfigurable WDM) [9] network management system prototypes.

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